PHYS 360/460 Experiment Summaries

(Updated May 2014)

1. **Speed of Light (6 weights)**

Determine the speed of light, *c*, using two methods: by using a variation of the Michelson-Foucault (rotating mirror) method and by measuring light from a pulsed laser that traverses different path lengths.

2. **Atomic Force Microscope (4 weights)**

Explore the nanoscale using an atomic force microscope (AFM). An AFM uses atomic forces between an atomically sharp tip and a surface to spatially image surfaces with up to atomic resolution. In this experiment, you will learn to operate an AFM and use it to image nanoscale features such as tracks on a CD or gold diffraction gratings.

3. **Ionization Potentials (3 weights)**

Determine the ionization potential of Argon gas. Operate a triode vacuum tube in the space-charge limited current-voltage regime to test Child's law. Deviations from Child's law will be used to determine the ionization potential of Argon.

4. **Thermionic Emission (4 weights)**

Verify the form of the Richardson-Dushman equation of thermionic emission using a vacuum tube and obtain a value for the thermionic work function of the tungsten filament.

5. **Coupled Oscillators (6 weights)**

The harmonic oscillator is a classic problem in physics with wide-ranging application in virtually all areas of physics. In this experiment, you will explore the mechanics of a coupled mechanical oscillator comprised of two pendulum connected by a spring. You will determine the force constants, normal modes, coupling frequencies and beat frequencies for the coupled oscillator system. Fourier analysis of the time dependent oscillations will be used to determine the frequencies.

6. **Ultrasonic Diffraction of Light (4 weights)**

In this experiment you will explore diffraction of light by a grating comprised of an ultrasonic standing wave in a liquid medium. Ultrasonic waves correspond to alternating compression and rarefaction of a medium at frequencies above audible. By forming an ultrasonic standing wave in a liquid a periodic variation in the liquids density is achieved. Since the optical index of refraction depends on material density, this standing wave can act as a grating, producing an interference pattern when laser light is transmitted through it. By measuring the properties of the diffraction pattern, you will determine the speed of sound and bulk modulus of different liquids.

7. Waves and Pulses in Cables (6 weights)

Co-axial cables are essential to measurement and communications technologies. They are also circuit elements unto themselves, having capacitance, inductance and resistance. Electromagnetic waves propagating in cables can be attenuated, phase shifted or reflected at the ends of the cable, depending on the frequency of waves, or pulse duration in the case of pulsed signals. In this experiment, you will investigate the propagation of waves and pulses in co-axial cables as a function of properties such as cable length, termination, EM frequency and pulse duration.

8. Frank-Hertz Experiment (4 weights)

Reproduce the classic experiment by Franck and Hertz demonstrating steps in the current vs. voltage for electrons passing through mercury vapor. This experiment provides important confirmation of Bohr model of the atom and quantum theory. The resulting spectra will be used to determine the energy level spacing in mercury as well as the mean-free-path of electrons.

9. Resistivity and Hall effect in *p* and *n* type Germanium (4 weights)

Measure the Hall coefficient, R_H, and electrical conductivity, σ, of *n* and *p* type Germanium to determine the electron (hole) carrier concentration, $n_{n(p)}$, and mobility, σ. In addition, determine the band gap in pure Germanium by measuring the conductivity. Although not required, it is beneficial to have taken PHYS 335 (Condensed Matter Physics) before this experiment.

10. Radio Frequency electronics and frequency stabilization (9 weights)

The goal of this experiment is to stabilize the frequency of a radio-frequency (RF) oscillator using an electromagnetic resonance of a copper cavity. You will set up and characterize a voltage-controlled oscillator and determine the resonant frequency, quality factor and reflection co-efficient of the resonator. You will then use the resonator to set up a feedback loop to stabilize the circuit at a particular frequency. Measurement of the frequency will then be used as an accurate measurement of the thermal expansion co-efficients of Al and Cu. Although not essential, it is beneficial to have done the Phys 360/460 experiment “Waves and pulses in cables” and have taken PHYS 352 (or 391) “Electronics” before this experiment.

11. Critical Point and Equation of State (4 weights)

In this experiment you will investigate the behavior of a gas through a liquid/gas phase transition. You will obtain the vapor pressure, determine the critical point (P_c, V_c, T_c) and evaluate the latent heat of evaporation using the Clausius-Clapeyron relationship. Trouton’s rule is also investigated.

12. X-ray diffraction (4 weights)
X-ray diffraction is a widely used tool to investigate the crystalline structure of materials. In this experiment, you will learn to use a monochromatic, 2-circle diffractometer to investigate the structural symmetry and lattice spacing in different elemental and binary powder samples. Although not required, it is beneficial to have taken PHYS 335 (Condensed Matter Physics) before this experiment.

13. Mass Spectrometer (4 weights)
In this experiment, you will use a quadrupole mass spectrometer to determine the mass composition of several gases including air, nitrogen, argon, neon and CO_2. This experiment will provide an important introduction to high vacuum technologies.

14. Nuclear Counting (6 weights)
In this experiment, you will explore the operation and characteristics of Geiger detectors and use a Geiger detector to measure radioactive beta decay from Cl^{36}. You will also examine the penetration depth of beta radiation, by attenuating the beta radiation with Al foil. This experiment will also allow you to explore aspects of counting experiments, such as statistical counting uncertainties and detector dead-time correction.

15. Gamma Spectroscopy (4 weights)
Use a Sodium Iodide scintillation detector and multi-channel analyzer (MCA) to determine the energy dependence of gamma ray emission from radioactive sources (Cs^{137}, Co^{60}, Na^{22} and Ba^{133} and Bi^{207}). You will analyze the spectrum, comparing to expectation, and examine the channels with which energy is lost in the detector crystal.

16. Waveform Analysis (4 weights)
Periodic functions can be analyzed in terms of Fourier components (sums of sinusoidal harmonics). In this lab, you will use a function generator to produce a variety of periodic waveforms (square, triangular, saw-tooth, …) and analyze the Fourier components of the waveforms electronically. The amplitudes and frequencies of the Fourier components will be compared to calculations. Although not required, it is valuable to have reviewed Fourier series in PHYS 364 “Mathematical Physics 1” prior to taking this experiment.

17. Analogue Computer (6 weights)
Operational Amplifiers can be arranged in configurations to perform mathematical operations electronic signals such as summation, differentiation and integration. In this experiment, you will demonstrate a series of mathematical operations using Op-amps, resistors and capacitors. It is required for you to have taken PHYS 352 (or 391) “Electronics” prior to taking this experiment.

18. Helium Excitation (3 weights)
Measure the quantized energy levels and ionization potential of He. By bombarding He vapor with energetic electrons, the He atoms can be excited to higher energy states or even ionized. By measuring the current in a critical potentials tube as a function of accelerating voltage, you will determine the energies of electronic transitions in He, showing that the allowed energy levels of electrons are in fact discrete, consistent with quantum theory.

19. Vacuum evaporation of optical thin films (4 weights)
You will use a vacuum evaporator to fabricate an optical filter, comprised of thin films of Aluminum and a dielectric material: (Na_3AlF_6) on a glass substrate. This filter is intended to transmit light at over a narrow band of optical wavelengths. The thickness of these films will be monitored during growth using a quartz crystal oscillator. A spectrometer provides optical transmission vs. wavelength data, and the transmission curve allows for determining the optical reflectivity of the film. This lab will introduce vacuum and thin film growth technologies.

20. NMR (9 weights)
This experiment uses a self-contained pulse NMR spectrometer to introduce several topics in pulsed Nuclear Magnetic Resonance. Investigations include; resonance and the free induction decay. Techniques such as inversion recovery and the Hahn echo are used to deduce the relaxation times T_2^*, T_2, T_1 of various soft materials and liquids.

21. N/A

22. Laser Raman Spectroscopy: Vibrational Spectrum of CCl_4 (4 weights)
Determine the vibrational frequencies of carbon tetrachloride using inelastic light scattering (Raman scattering). With Raman scattering, energy shifts of the scattered radiation are used to determine the normal-mode vibrational frequencies of CCl_4. In addition, by varying the polarization of the incident light, aspects of the symmetry of the vibrational modes can be determined. From the vibrational frequencies and symmetry, it can be deduced which vibrational modes the frequencies correspond to. Using a valence force model, this information can be used to determine the force constants acting on the C-Cl bond. Finally, by determining the ratio of the Stokes to anti-Stokes scattering, the temperature of the sample can be determined.

23. 1D lattice dynamics (4 weights)

Use a row of sliders on air track coupled by springs to model a 1D lattice, with the massive sliders and springs connecting them corresponding to "atoms" and "bonds", respectively. The frequency, ω, vs. wavelength, k, of the 1D lattice will be determined from both a "monatomic" lattice (all sliders of same mass) and "diatomic" lattice (2 different masses). Drawing an analogy to lattice vibrations (phonons) in materials, you will determine the speed of sound, acoustic and optical branches of ω vs. k , the band gap and Debye frequency, ω_D. Although not required, it is beneficial to have taken PHYS 335 (Condensed Matter Physics) before this experiment.

24. N/A

25. Acoustic Measurements (3 weights)

In this experiment, you will employ a commercial audio analysis system (CLIO) to examine the frequency response of low and high pass filters, determine the speed of sound in air, examine the frequency response of a loudspeaker, and investigate reverberation time, and how the room's acoustical properties affect it across a range of frequencies.

26. Pound-Drever-Hall frequency stabilization (9 weights)

This lab is an extension of Exp. 10, making use of the same RF electronics apparatus. The goal of this experiment is to stabilize the frequency of a radio-frequency (RF) oscillator using an alternate scheme called Pound-Drever-Hall frequency stabilization, which uses a modulated voltage-controlled oscillator.